ROLE OF RESEARCH IN SOLVING HIGHWAY AND URBAN PROBLEMS

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Joint Highway Research Project

by

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PURDUE UNIVERSITY
LAFAYETTE INDIANA

Final Report

AIRPHOTO INTERPRETATION OF ENGINEERING SOILS OF

KOSCIUSKO COUNTY, INDIANA

TO: E. B. Woods, Director
Joint Highway Research Project

June 3, 1960

File: 1-4-28-32

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

Project No.: C-36-5E

The attached report entitled "Airphoto Interpretation of Engineering Soils of Kosciusko County, Indiana," completes a portion of the project concerned with Engineering Soils Mapping, [illegible]. The report was prepared by P. T. Yeh, Research Engineer, and [illegible], former research assistant, Joint Highway Research Project.

The soils mapping of Kosciusko County was done primarily by airphoto interpretation. However, the soil symbols are modified by field investigation. To increase the value of the county soil maps, [illegible] soil types were sampled and tests were performed in the soil laboratory. The soil testing data included grain-size analysis, plastic [illegible] limit, optimum moisture content for maximum dry weight from the [illegible] proctor test and CBR. The soils were classified using the [illegible] Classification System and the Bureau of [illegible] Soils System.

An ozalid print of the engineering soils map [illegible] the appropriate classification [illegible] included in the back of the report.

Respectfully submitted,

H. L. Michael, Secretary

HLM:cw

Attachment

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at large.

University. Finally, the picture would be warped indeed without acknowledgment of the truly great research contributions of the Bureau of Public Roads, the highway industry itself, plus contributions from foreign sources, as for instance, the British Road Research Laboratories.

<u>Early Research Contributions</u>

In 1959 this author (2) raised the question as to whether [illegible] Civil Engineers of this country could have handled a highway program [illegible] the current one, 30 or 40 years ago. A quick survey [illegible] 1920 and 1930 will show without question [illegible] ly inadequate to cope with modern highway problems. [illegible], the collective research contributions of Highway Departments, [illegible] Federal Government, materials producers, added to the great efforts of [illegible] of the Highway Research Board, American Association of State Highway Officials, the American Society of Testing Materials, have made [illegible] Highway Departments to execute their present responsibilities [illegible] general to meet the demands of this tremendous [illegible] credit of the Bureau of Public Roads [illegible] to pursue basic programs of research have been [illegible] findings which can be used to guide the financing, planning, design, and operation of these modern highways.

In considering the low state of the [illegible] of [illegible] ago it is surprising to note an extensive [illegible] in service—with a considerable mileage still being used as bases for newer pavements. Some concepts of basic design were developed and are [illegible] through controlled test sections and test roads designed specifically for this purpose. Examples of such projects are the field experiments conducted by the Bureau of Public Roads at Arlington, Virginia (3), and Connecticut Avenue, Washington, D. C. (4). At the same time the results from the "Bates Test Road"(5)

established a pattern of design which lasted until about 1945. During and after the second World War, pavements constructed under these design concepts failed badly, especially in sections of the country where clay-like soils predominated and under conditions of a high volume of heavy loads (6). The need for a new design approach was thus indicated (120, 124). Test roads [illegible] Highway Research Board [illegible] road project [illegible] Maryland (6). The [illegible] Association of State Highway Officials [illegible] so-called [illegible] Road Test (7, 8) [illegible] 23-million dollar [illegible] Road [illegible] was conceived, built [illegible] still under test.

During this 40-year period [illegible] test roads, a wide variety of [illegible] was performed in the laboratories of the Bureau of Public Roads, universities, State highway departments, [illegible] and others. [illegible] Highway [illegible] Road [illegible] this [illegible] the [illegible] known Highway Research Board was organized in 1920 under [illegible] National Research Council [illegible] the National Academy of [illegible]) The American Association of State Highway Officials was organized in 19[illegible] [illegible] (12). [illegible] 15, 16), and "bituminous [illegible]" roads (17). Bituminous [illegible] on city streets long before the turn of the century and by 1910 [illegible] was available (18, 19). [illegible] (20, 21) [illegible] and the [illegible] great detail (22, 23, [illegible]). Such [illegible] (25), [illegible] (26), [illegible] Burton and Benkleman ([illegible]), Boyd (29), and Terzaghi ([illegible] 31, 32) began [illegible] in the literature during this period because of increased interest in [illegible] subgrades. The classical work on the gradation of aggregates and the development of the well-known "Fuller's Curve" was published in [illegible]907 ([illegible]) [illegible] efforts placed on highway construction, research programs were expanded [illegible] fields of materials research. Committee D-4 on Road and Paving Materials of

the ASTM was organized in 1904, primarily to develop methods of tests and specifications for pavements including wood block, granite block, brick, and bituminous mixtures. Committee C-9 on Concrete and Concrete Aggregates was formed in 1914 under the leadership of Sanford E. Thompson (33) but Committee D-18 on Soils for Engineering Purposes was not organized until 1926.

Soon after 1920 interest was evidenced in nine of the broad aspects of highway engineering including finance (24), economics (31, 36, 37), traffic [illegible] (34, 39, 40, 41, 42, 43, 44), and the relationship of highways to other [illegible] transportation (15, 19, 45). The current great interest in continuing [illegible] on these and many other aspects of highway engineering is indicated by [illegible] that over twenty-six hundred people were registered at the January, 1956 [illegible] meeting of the Highway Research Board in Washington, D. C.

Early Cooperative Highway Research [illegible]

One of the most outstanding [illegible] [illegible] [illegible] State University and the Ohio Department of Highways [illegible] started in 19[illegible] by Professor [illegible] [illegible] [illegible] professor [illegible] [illegible] [illegible] made by [illegible] [illegible] to the [illegible] [illegible] [illegible] engineers [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] (18, [illegible]) [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] department, and [illegible] [illegible] [illegible] include [illegible] tensive laboratory [illegible] and [illegible] [illegible] [illegible] of 15 [illegible], [illegible] judgment of a personal opinion that Professor [illegible] [illegible] [illegible] [illegible] the [illegible] [illegible] recognized the need for [illegible] [illegible] of [illegible] [illegible] of [illegible] [illegible].

[illegible] [illegible] [illegible] [illegible] [illegible] ment cooperation was that reported by [illegible] et al in 19[illegible] ([illegible]), [illegible] outstanding information [illegible] developed for the Bridge Bureau [illegible] [illegible] determination of pile requirements for bridge foundations.

A little later, in 19[illegible], the author was privileged to report [illegible] Ohio State Engineering [illegible] [illegible] [illegible] five years of [illegible] [illegible]

the Bureau of Tests in the general field of highway soil mechanics (54). Included in this report was one of the early sets of typical embankment control curves averaged from 461 Ohio soil samples tested in 1936. This work has been continued and in 1958, Joslin (55) presented curves averaged from 10,000 samples. The curves are widely used on various types of earthwork throughout the [illegible].

Other examples of cooperative work between the University and the Highway Department can be cited--however, these represent occasional cases and indicate a long-time spark of interest on the part of both organizations [illegible] highway research. Then too, this has long been well-implemented by [illegible] and other members of the staff of the Bureau of Tests and by [illegible] the central office, and by members of the University staff on committees [illegible] meetings of such well-known organizations as the Highway Research Board of the National Research Council, the American Society of Civil Engineers, The American Society for Testing Materials, and American Association of State Highway Officials, American Concrete Institute, Association of Asphalt Paving Technologists, and others.

Significant to the above mentioned cooperative programs is the fact that all three involved highway soil mechanics. Consider for a moment the potential if the entire spectrum of highway engineering is opened for joint research efforts. Highway engineering, in the broad sense, stretches beyond the scope of Civil Engineering itself, touching as it does on finance, administration, [illegible] economics, engineering law and even the broad field of [illegible]. These disciplines are in addition to the conventional Civil Engineering [illegible] such as Structural Engineering, Soil Mechanics and Foundations, Materials, Construction, Traffic Engineering, and Operations. The great schools and universities of this country and Canada are equipped, and are interested in being of service to the separate highway departments.

Cooperative Highway Research Programs

With the great scope of unsolved problems encountered in the highway field, it is only natural that the practicing highway engineers in the federal, state and local governments and the professional staffs of the institutions of higher learning would become interested in joint research efforts. This type of program have been developed in the separate states of the United States and in some of the provinces of Canada. As a general rule, the cooperative efforts between Highway Departments and universities--and frequently with public roads or transportation third party--have two main objectives, namely (a) the solution of problems confronting the highway agency by the application of research and engineering which may be immediate or long range problems, both basic and applied in nature, and (b) the encouragement of graduating young engineers to pursue graduate programs in Civil Engineering so that they may be able to contribute through their own research and through teaching in universities or in the employ of federal, state, local government agencies, or the highway industry in general. It is important to note here that the highway industry should have a considerable responsibility in contributing to research and development and to the fellowship programs of our colleges and universities dedicated to graduate study.

Many of the cooperative programs have been very successful. Iowa State University and the University of Illinois have had long-term informal arrangements with the Iowa and Illinois Highway Departments respectively in addition to the Bureau of Public Roads participation--the latter under the Hatch Act. In more recent years, more formal arrangements have been initiated in both states.

Both formal and informal arrangements between the Highway Department and a college or university are common in the United States and Canada--a trend in developing cooperative highway research programs, with public roads as one of the sponsors is increasing rapidly. Among the states with informal arrangements can be listed Florida, Kansas, Maine, Minnesota, and Texas. Various types of

Indiana's JHRP

One of the early cooperative highway research undertakings was the Joint Highway Research Project started informally at Purdue University in 1936 (J.H.R.P.). In organization was established as a result of an agreement between the Chairman of the State Highway Commission of Indiana and the Head of the School of Civil Engineering at Purdue University. During the first year the Indiana bill was $25,000 for research and on March 11, 1937, the organization was established by an act of the State Legislature which permitted the Commission to allocate $50,000 annually for the operation of the research organization. In 1949 the Legislature revised the 1937 act, to raise the maximum amount the Highway Department may allocate to the University. The offices and laboratories are located in the Civil Engineering Building at Purdue University.

Close contact is maintained with the Highway Department through an Advisory Board. The Board outlines policy, receives and recommends projects, receives reports on projects, approves release of research data, and recommends to the Highway Department and the University the annual amount to be allocated for research. In accordance with the program of research, the Highway Department nominates problems to guide the research endeavors toward the most pressing Indiana highway problems and to apply quickly the knowledge gained. In turn, the University Board members and staff are better able to guide the University research toward the most useful research projects designed to solve some of the highway problems in Indiana.

The Highway Research Project is a unit in the Engineering Experiment Station and is administered by the Head of the School of Civil Engineering, who serves as Director. At the present time there are nine research divisions, as follows: Soils, Concrete and Rigid Pavements, Bituminous Materials and Flexible Pavements, Airphoto Interpretation, Chemical, Traffic, Location and Administration, Structures, and Hydraulics. These divisions are the scene of research work and the

area of research programs, and most of them are the source of educational courses at the graduate and undergraduate level. At the present time, the staff of the project includes 24 full-time employees and 15 half-time graduate research assistants. From 50 to 75 undergraduates are employed on a part-time basis to assist on research projects. In addition to the many hours of research [illegible] produced by the staff in the 4-year period of the project's existence, [illegible] progress reports have been released from time to time (Fig. 5), [illegible].

Some Projects of the JHRP

In presenting a few highlights covering the [illegible] of the [illegible] Highway Research Project, the research projects are divided into [illegible] of State and local interests, and those of State and national interest.

Soil Mechanics and [illegible] Work. An ideal area [illegible] in the field of distribution and engineering characteristics of soils. [illegible] especially true in the Midwest where strong research and [illegible] programs [illegible] developed as at Purdue University [illegible] here at Ohio State, for instance. The [illegible] Highway Commission [illegible] feels strongly that one of [illegible] to their program [illegible] the [illegible] on Indiana Soils (61) [illegible] A [illegible] on [illegible] soils [illegible] of Indiana [illegible] the soil survey [illegible] was studied and [illegible] Research has continued for the past 17 years in refining engineering soil boundaries in various studies of Indiana (11). [illegible] that this work will [illegible] of a new Indiana project which [illegible] Research Project with the Purdue Agricultural Experiment [illegible] Conservation Service, and the Bureau of Public Roads. This [illegible] research is almost ideal for the [illegible] of Ohio, [illegible] programs can be greatly [illegible] be provided [illegible] ing properties of the [illegible] materials of construction.

At Purdue, interest has continued for 20 years [illegible] in connection [illegible] fundamental properties of soils, such as frost action (6[illegible], 63), soil [illegible] (64, 65, 66, 67), base courses for rigid and flexible pavements ([illegible]), the pumping of pavements (69, 70), and soil explorations for highway projects ([illegible], 72, 73, 74, 75). Included among some unusual soil studies is the work of [illegible] et al (76), on deflection measurements made from deep-seated bench marks (76);

and the very interesting work of [illegible] (77) on the use of [illegible] protection for highway subgrade soils.

The Joint Highway Research Project also operates a [illegible] photo [illegible] tation and photogrammetric research laboratory. This [illegible] the art of airphoto interpretation and the science of photogrammetry [illegible] to the location and planning of urban areas and highway systems. The laboratory is primarily concerned with the development of the use of aerial survey [illegible] ate watershed characteristics, engineering soil types, location of [illegible] borrow materials, and special applications of photogrammetry.

The State of Indiana [illegible] only [illegible] of the [illegible] 1/24,000 topographic [illegible] individual counties was [illegible] in the mid-1940's [illegible]. The aerial photographs were used to delineate ephemeral and perennial drainage channels. [illegible] 92 counties have been completely mapped [illegible] County [illegible] a scale of 1 inch equals 2 miles [illegible] data on the drainage [illegible] for planning purposes (79).

The photogrammetric section develops special studies that cannot be scheduled in the highway department's photogrammetric laboratory (80). [illegible] students have worked on such studies as the "Photogrammetric Measurement of Pay Quantities in Highway Construction." Another project [illegible] land-use development at selected interchanges [illegible] Indiana to determine [illegible] for right-of-way [illegible] (81). Some interesting [illegible] has also been completed in the use of aerial strip photography for various highway and airport applications, including the [illegible] of performance [illegible]

Concrete and Concrete Aggregates. A second very practical area for cooperative research is in the field of materials of construction. Each of the geographical, geological, and major political units of the continent may have problems with materials, peculiar to the particular unit, and not necessarily in common with adjacent areas. Ohio may have problems in common with surrounding states, i.e., Pennsylvania, West Virginia, Kentucky, Indiana and Michigan. However, it is likewise true that all of the problems with native materials in Ohio are not in common with any of these sister states. It is practical then to consider a state-wide, cooperative research program on the distribution and engineering characteristics of the materials commonly used in highway construction.

Only again the highway research in Indiana as an example, laboratory and field programs have been underway for about 20 years--and the laboratory program are being continued. One of the early contributions was made possible through detailed studies of the performance of concrete pavements. The research produced a direct correlation between the source of coarse aggregate used in construction and the satisfactory or unsatisfactory performance of the pavements (13*).

* This paper was chosen as the 1945 Highway Research Award.

Furthermore, it was observed that the susceptibility to blow-ups was an influence of the use of poor-quality, non-durable aggregates, which when in service, resulted in short life--especially in areas of severe frost with soil types of clay-like characteristics. This research was of great importance in developing specifications (84, 85) for portland cement concrete aggregates but it also had a significant influence on the design of rigid pavements in connection with the abandonment of the practical use of expansion joints. This work led to many detailed laboratory studies of aggregate and of concrete. Chemical investigations were reported by Slate (86, 87). Indiana limestone aggregates were further

studied in an effort to understand their performance in frost action. The study involved the porosity, permeability, and absorption properties of the materials and good correlations were obtained between these properties and the durability factors. Some of this work was reported by Yoder, Dolch, and Woods (87) and more recently by Dolch (88). The gravel aggregates of Indiana have received much research attention with special emphasis on chert and other deleterious substances (90) together with corrective measures which might be employed (91). The effect of structural cracks in the stone (92) and fatigue of air-craft airport pavements (93) have also received attention.

Pavement slipperiness and pavement design from this viewpoint are becoming very important as the volume and speed of traffic continues to increase. Materials from which pavements are made need to be re-evaluated from the standpoint of their resistance to the polishing act on of traffic (94). The ramifications of this problem are many and, in any particular state, research is needed to help the highway engineer in the use of materials and design of mixtures to provide the best answers to the problem. The Joint Highway Research Project has undertaken laboratory studies to classify materials as to polish resistance (95). The air void content problem has been investigated to provide the information necessary to utilize most of the materials available. The most recent work on this problem concerns the use of available sands for producing mixtures for air-entrained concrete. The laboratory sand-mix study has evaluated such factors as particle shape, void content, and sand grading (96). The cooperative study has now been carried to the field for the purpose of developing field data to correlate with laboratory results and thereby to establish specifications and design criteria (97).

Bituminous Materials Research. Bituminous materials and bituminous-aggregate mixtures are receiving increasingly greater attention in highway research laboratories as a result of (a) continuous increases in the traffic volume and loads (b) increasing use of bituminous mixtures for flexible pavement construction and for resurfacing. Again, some of the research of the Joint Highway Research Project can be used to illustrate how a University-Highway Department cooperative program can function to provide research data for use in solving current highway problems. The basic, long-time program which has been underway almost since the inception of the cooperative work at Purdue, is concerned with the fundamental characteristics of bituminous-aggregate mixtures as related to their ability to carry traffic loads. In Indiana, this involves a very wide range of mixtures which are used under a variety of conditions of service, ranging from light secondary surfaces to high-grade bituminous concrete. This kind of long-time program requires frequent observations of field performance and great effort on the part of the research team to develop correlations between performance and laboratory methods of test. Durability of mixtures is of course another major subject for research.

One of the outstanding contributions in this area of research has been the long-term study covering the evaluation of several laboratory tests pertaining to the design of the mixtures and performance of those mixtures under traffic. An early study of this kind covered evaluation of the Hveem stability [illegible] as a method of indicating strength values (93). [illegible] with an evaluation of the Hveem Stabilometer method as a strength test, particularly as applied to mixtures of the open type and as opposed to the dense mixtures to which the test is normally applied (99). In evaluating Marshall and Hveem methods, use was made of rational tests such as unconfined and triaxial compression (98, 100). One of the most important aspects of mixture design for any construc-

tion agency is the evaluation of mixture variables as affected by the materials available for use. Many of the studies cited above bear on this problem (98, 99, 100). The evaluation of such factors as aggregate shape, both in the coarse and fine aggregate, is a case in point (101, 102). At Purdue there has been a continuing effort to understand better the effect of load variables, as determined by service conditions, on deformation characteristics of bituminous mixtures. Temperature, confining condition, rate of loading and repetition of load are the major factors studied (103, 104). The application of the concepts derived from such studies in order to give practical values to laboratory properties requires close cooperation between the laboratory and the field and a close University-Highway Department relationship. Mix design procedures have been modified to fit the conditions in Indiana (105) and performance data are obtained through test sections installed by the Highway Department and evaluated by Purdue personnel (106).

Another area to which the research organization has been able to make significant contributions concerns the durability characteristics of bituminous mixtures. The nature of this problem is such as to make evaluation difficult, but fundamental relationships have been brought out by laboratory studies (107). The application of the sonic test to the stripping resistance of bituminous mixtures, because it is a non-destructive type of test, has enabled long-time tests to be undertaken along the way to solving this problem (108).

Traffic Engineering and Highway Planning. In recent years Joint Highway Research Project efforts in the areas of traffic engineering and highway planning have been expanded and the outlook is for continued expansion, especially in urban planning and transportation economics. These contributions to the Indiana transportation system and specifically the State Highway Department of Indiana have been of major importance. Some of the studies which have proved particularly valuable are studies of highway impact, highway "needs," traffic accidents, the characteristics of traffic on Indiana highways, origin-destination surveys, the location of slippery road sections, roughness of highways, administration and organization of state and local highway departments, and county highway planning.

The initial studies of the impact of highway bypasses are well known and specifically in Indiana resulted in a broader and wiser application of the principle of controlled access (109, 110, 111). Impact studies are continuing and currently an attempt is being made to evaluate the influence on an urban area of a major highway improvement and the impact in rural and urban areas of a section of the Interstate System. The project staff with the assistance of personnel from the State Highway Department conducted a "needs" study of the highway system in Indiana, which contributed heavily to the passage by the State Legislature, and the almost universal acceptance, of legislation which in turn provided much needed highway revenue (112, 113). Much information obtained in this study is currently being used in highway planning in Indiana and a sufficiency rating study which was a part of the needs study provided the impetus for the adoption by the State Highway Department of this priority tool.

In the area of traffic safety, recent research projects have developed relationships between elements of the roadway and accidents, and methods of analysis have been developed which provide for the determination of the causes of accidents at many high-accident locations (114). The application of the results

of this latter research resulted in the finding and the subsequent elimination of a major cause of accidents at 27 out of 33 high-accident locations. Research just completed in this area has also produced a technique of accident analysis which results in the efficient location of slippery pavements on highways so that they can be "deslicked." The method not only locates slippery sections but also assigns a priority of remedial action which considers the slipperiness of the pavement and the volume of traffic on the highway. The technique provides a selection of sites which correlate very well with the actual sites determined by the vehicle stopping distance method, a technique which also was developed by research in the Joint Highway Research Project. Staff members have also cooperated with the Metropolitan Survey Unit of the State Highway Department and have assisted in the preparation of origin and destination surveys while at the same time using the data for research on methodology, usefulness, use of these surveys. Origin and destination studies have now been conducted for the past 20 years and these studies along with a study of the volume characteristics of traffic have been of value to the Highway Planning Survey Unit of the State Highway Department. The project also developed a roughometer for the Highway Department and has delivered it to them for their regular use (continued).

Local roads have also received attention in project research and the development of practical methods of local road identification, classification, priority of improvements have been developed (11, 16). In order to provide assistance to local authorities of cities and counties a Traffic Engineering Service Unit has been established to advise and study local problems (17). This Unit receives many requests for assistance from local authorities and the good public relations and subsequent improvements in highway travel in these communities are obtained with a small expenditure of time and money.

Other Important Studies. The project also cooperates with the Highway Planning Survey of the State Highway Department by conducting some research studies

which are partially financed with Highway Planning Survey funds. At the present time several such studies are in progress including research on the hydraulics of Arch Bridges (118). The breadth of Indiana's highway research program is further reflected by the work done in economics (119), finance (120), structures (121), and design (122, 123, 124).

Urban Research

Highway transportation is deeply involved with all other methods of transportation and especially with the entire problem of urban development. Work in this area needs immediate attention and your author strongly recommends careful consideration toward the development of strong programs in both areas. Many highway departments are already interested and there is much interest on the part of the Bureau of Public Roads.

Woolbury in his excellent report presented at the January, 1960, meeting of the Highway Research Board (145) in his concept of a new pattern of urban development, states that "More than two-thirds of the national population increase is going into standard metropolitan areas outside of their central cities." He also concludes that "...shockingly little is being done to understand this major phenomenon of the times or to prepare for coping with its problems, or for making the best of the opportunities it presents." Mavis commented at the same meeting (126) that, "It seems obvious that research into the problems of the functioning of the urban complex requires bringing into play the competences of a number of disciplines...." In the transportation and related fields important areas for immediate attention. To name a few topics, consider some of the following:

1. The development of better standards and techniques for origin and destination surveys.

2. Commuting and mass transit, including costs, finance, and use.

3. Inter-community travel.

4. Parking and storage terminals.

5. Expressways, bypasses, subways, and use of helicopters.

6. Inter-fringe travel, trip length, and limited access.

7. Problems in the field of political science, including city and town governments, zoning, inter-government relations, authorities and commissions, and inter-agency relationships.

8. Legal and engineering problems such as land acquisition and control, use of eminent domain, building codes, government ownership, and control of traffic.

9. Economics -- i.e., use of natural resources, residential-business-industrial patterns, land use, ownership of utilities, etc.

10. Public and private housing, and slum clearance.

11. Use of water for power, cooling, etc., flood control, sanitary engineering, and services and utilities, public health and hospitals.

12. Urban development in general.

13. Problems of finance such as taxes, rentals, bonding, private, state and Federal grants, bond issues, etc.

14. Problems of fumes and noise.

In looking at this problem it should be noted that much research has been performed and that a great deal more is underway. Publications of research findings are widespread including suggested programs of research (1, 7, [illegible] 130).

Conclusions

One of the best summaries this writer has seen on the value of highway research has been made by Davis (126) in his chairman's address to the [illegible] meeting of the Highway Research Board. He summarized the report prepared by Mr. D. P. Holveck of the Bureau of Public Roads as follows: "...the total estimated that research activity related to highway affairs in the United [illegible] in 1954 involved an expenditure of some $[illegible] million, which was [illegible] the direct expenditures for highways (including design, construction, [illegible] and administration) in that year of almost 10 billion dollars. The investment in research would thus appear to be only of the order of 2 mills per dollar of direct expenditure on roads -- a remarkably small proportion of [illegible] is commonly necessary industries to be an adequate investment in the solution of future problems."

It has been a pleasure to have had this opportunity to have been [illegible] I hope my brief remarks will encourage some of you to pursue projects of highway research.

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